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## THE HYDROGRAPHY OF YUGOSLAVIA

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The prominent hydrographic characteristic of Yugoslavia is its richness in water. There is the Adriatic Sea with a 1,916-kilometer-long coastline extending from the mouth of the Mirna to the mouth of the Bojana. There are many lakes, a considerable number of rivers of various length, and very many cold and warm springs and wells. The principal hydrographic characteristic prevailing in karst areas is that of underground rivers.

### THE SEA

The largest body of water in Yugoslavia is the Adriatic Sea. The smaller half of its total area, about 55,000 square kilometers, belongs to Yugoslavia. The open sea is more often disturbed than channels and bays, especially in the winter months from October to February, when the Adriatic is strongly agitated by the bora and the south wind (jugo or silok). The bora creates choppy waves, usually under 2.5 meters in height, which cross each other and impede shipping. The south wind causes the highest waves, 3 to 3.5 meters, mostly regularly shaped and crested. The waves caused by this wind are very often more than 30 meters in length. The channels considerably influence the waves because the waves must follow their course. Therefore, it often happens that waves caused by the same wind enter the open sea from different directions, cross each other, collide, and create whirlpools which are dangerous to shipping.

The flow and ebb of the tide does not occur on the entire Adriatic at the same time because the tidal wave is pushed to the right by the powers of attraction that cause its deviation. Therefore, high tide appears in Korcula at 0400 hours, in Zadar at 0600 hours, and in Krk at 0800 hours (see Figure 1 below), while on the opposite, Italian, coast the tide ebbs at the same times.



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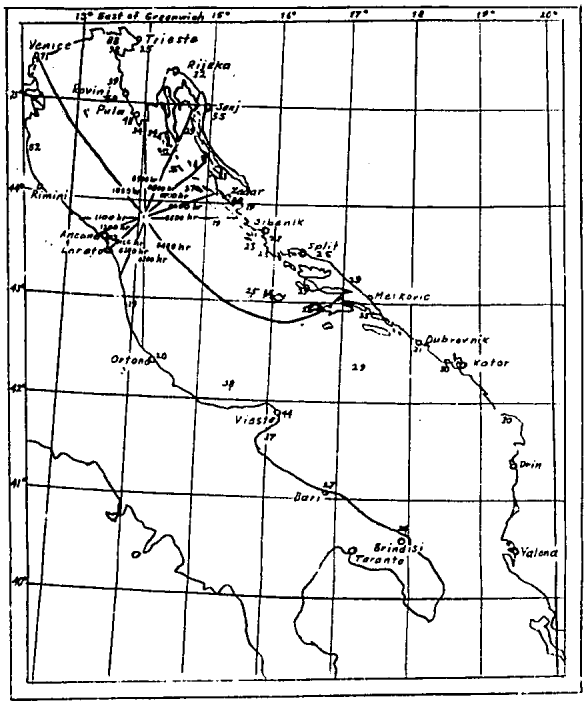


Figure 1. Tide Table of Full Tide (lines drawn between coast and islands) and Middle Levels Between Flood and Ebb in Centimeters (figures apply to the coast and islands)

The difference between the tide's flow and ebb is slight in the deep southern basin of the Adriatic (in Kotor and Dubrovnik, 30-31 centimeters), and quite wide in the shallower northern basin (in Pula, 48 centimeters; around Trieste, 85-98 centimeters). These tidal changes are not of equal duration. In some channels during quadrature phase (when sun and moon, observed from the earth, from an angle of 90 degrees), there is only one flow and one ebb of the tide within 24 hours; this especially holds true in Zadar channel and around Rijeka.

Information on currents in the Adriatic from seventeenth century sources is quite in agreement with the latest research. The sea current enters the Adriatic through the Straits of Otranto. It moves along the Yugoslav coast as a northwest current (the currents are named by their direction of flow). Smaller branches separate from the current at Kotorski Zaliv and turn to the left into the open sea, this especially between Dubrovnik and Korcula. The average velocity of the northwest current is about 7.2 kilometers per day, but it becomes faster in the central Adriatic, from Herceg-novi to Vis (about 13 kilometers per day), than southward (7.5 kilometers per day) or northward (4 kilometers per day).

Among other characteristics of the Adriatic Sea, its temperature is of special importance. The temperature on the surface and in minor depths is subject to insignificant annual changes because of the geographic location of the sea and the high specific heat of the water, and especially because of the high winter temperature. The annual difference in temperature in Mali Kvarner is about 14.5 degrees centigrade; it decreases southward, so that it is 11 degrees centigrade southwest of Dubrovnik in the open sea. In winter the temperature increases from the north toward the south and from the coast toward the open sea.

The lowest temperatures are at the mouths of large rivers. The temperature is also comparatively low in Kotorski Zaliv. The surface temperature of the open sea in winter is 7-8 degrees centigrade higher in the southeast Adriatic than in the northwest Adriatic. The difference in the surface temperatures in the open sea is insignificant in summer: the average temperature in the north is 22 degrees centigrade, and the south 25 degrees. The evaporation is quite rapid on the Adriatic because of the high temperature. The result is high salt content and high water transparency. The transparency of the clearest water compares with that of the tropical seas. The Adriatic is the most transparent around the deepest places, that is, up to 50 meters; it is less transparent in the open sea in the northern, shallower basin, 30-45 meters in depth, and still less so along the coast and at the river mouths.

Sea water has the very peculiar ability to purify itself: it separates the suspended organic and inorganic particles as a sediment within a very short time, with the process being more rapid in warmer water. This is why the open waters of the Adriatic are clearer than some colder seas, as for instance the Baltic Sea.

The salt content of the Adriatic's water near the surface increases from the northwest toward the southeast, along with the temperature (on the average from 33 to over 38 per mill [meters per 1,000 meters]). The salt content increases slightly as the water gets deeper. The high salt content of the Adriatic equals that of the central part of the Mediterranean Sea.

The color of the Adriatic is related to the tranparency and the salt content. The blue color of the water increases with heightened salt content. Nearer the coast and around the mouths of rivers, it becomes green. The color depends greatly on some other factors, such as the elevation of the sun, the presence of clouds, water movements, depth, color of the bottom, etc. The most beautiful actions of light can be observed in the Blue Grotto (Modra Spilja) on the east side of Bisevo Island. The cave is colored an intense blue.

The Adriatic has strongly-developed convection currents -- vertical movements of the water -- because of its physical and chemical properties. This shifting of water masses equalizes the temperature, salt content, and oxygen content from the surface to the bottom. The great thermal importance of the convection currents can be seen by the fact that, during the summer half of the year, they store 350,000-450,000 kilogram-calories of heat in a column of water 60-70 meters deep and one meter square. The same quantity of heat is released during winter. This is the reason for mild winters along the Adriatic, even in the coldest months.

The above-mentioned water movements explain the richness of the Adriatic's oxygen content, very important factor for maintaining the balance of life in the sea. The oxygen content of the surface water is very seldom below 96 percent and increases sometimes up to oversaturation. Even at maximum depths, as a rule, the oxygen content does not fall below 80 percent.

The oxygen content of the Adriatic, provided by strong waves and vertical water movements, is very important for the existance and development of flora and fauna, especially of fish. Fishing is very well developed among the coastal population.

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## LAKES

The abundance of fresh continental waters is the result of the mountainous relief of Yugoslavia, particularly of the impermeable soil and favorable climatic conditions. Among the climatic conditions for lakes and rivers, the most important is the geographic distribution of atmospheric precipitation in individual months and in the season of snow thaws, especially in mountain areas. Lowlands and plains, with river and mountain valleys and fields, occupy about 63,000 square kilometers, an area somewhat larger than one fourth of all Yugoslavia's territory. The rest of the area consists of hills, mountains, and mountain ranges.

There are many lakes in the country of various origins at least so far as the formation of their beds is concerned. Altogether, however, they do not occupy more than 740 square kilometers, or 3 percent of the Yugoslav territory. Some of these lakes are of tectonic, some of karst, some of ice, and some of fluvial origin. Most of the lakes were formed by simultaneous or alternating action of several forces and not solely by the single action of one certain force. The largest number of lakes are fresh water. However, some of them close to the Adriatic coast are salty water.

The large lakes are located at the frontier with Greece and Albania. The largest one is Lake Scutari, the deepest one is Lake Ohrid, and the highest one is Lake Prespa. The beds of lakes Ohrid, Prespa, and Doiran are of tectonic origin. They are located in depressions more or less in a meridian direction. The first two lakes show karst influences. The bed of Lake Doiran is in an oval valley between crystalline slates of Paleozoic formation. It is surrounded by hills; to the north is Belasica Mountain. Two other lakes are surrounded by high mountains and are at a high elevation themselves: Lake Prespa is 853 meters and Lake Ohrid is 695 meters above sea level.

Lake Prespa, with an area of 285.4 square kilometers (186.2 square kilometers belong to Yugoslavia), has an irregular shape. Its larger part is 18-20 meters deep. There are two depressions on its bottom, like two valleys, where the lake is 34.5 and 54.9 meters deep, respectively. The lake receives its water through several small streams from the surrounding mountains. Its water disappears under the ground through the Zavir abyss and several smaller ones. This water appears on the surface on the western slopes of Galicica mountain in the form of several wells and flows into Lake Ohrid. The water level of Lake Prespa fluctuates during the year between 1.5 and 2 meters because of changes in water influx. The lake's temperatures are similar to those of Lake Ohrid. The average temperature of the water is 23.4 degrees centigrade in summer and 2.9 degrees centigrade in winter. The water is, on the average 2.1 degrees warmer in autumn than in spring. The temperature is almost completely equalized in winter (isothermy) at depths of approximately 32 meters. On 24 December 1931, on 16 January 1932, they were between 4.1 and 4.2 degrees. In summer the temperature decreases with the depth, the temperature dropping 8 degrees centigrade in water 14-16 meters deep.

Lake Ohrid is of quite oval shape with an area of 366.7 square kilometers (247.8 square kilometers belong to Yugoslavia). This is the deepest lake of the Balkan Peninsula. Approximately 140 square kilometers of its bottom, or 40 percent or the entire area, is more than 200 meters deep, and the deepest sounding made is 285.7 meters. Although many small streams feed the lake, it receives much more water from the wells and springs on its limestone periphery and on its bottom. Therefore, Lake Ohrid has a very narrow drainage area, which conditions somewhat its physical properties. The Crni Drim carries the water from the lake.

Much data is available on the thermal situation of this lake. Lake Ohrid has a surface temperature of 18-28 degrees centigrade during the summer daytime hours. The surface of the lake is, on the average 0.7 degree colder in the morning than in the evening. Daily temperature differences are 3.6 degrees

centigrade in summer and 1.3 degrees in winter. The average surface temperature in May (about 15 degrees) is considerably lower than in September (about 21.2 degrees). The temperature rapidly decreases from the surface toward the bottom during the warmest month. At the bottom it is no higher than 5 degrees centigrade (at least this condition obtained in 1926-1928). The lowest temperature of the lake is in February (7.2 degrees), and the highest in August (24.2 degrees). Accordingly, the annual difference in temperature on the surface is slight, 17.0 degrees centigrade. The periods of lowest and highest temperatures develop a considerable length of time after the solstice, a characteristic property of sea surfaces. Lake Ohrid has two temperature jumps during summer: 15-20 meters deep the difference in temperature is 2.4 degrees centigrade and 25-35 meters deep the difference is 4.7 degrees. But temperature levels shift to greater depths at the end of summer: the first one, to between 30 and 45 meters, and the second one, to between 50 and 60 meters; the differences in temperature also become greater. The lake never freezes in winter, except for a narrow belt along the shore.

Lake Ohrid is extremely clear because very few particles are suspended in its water, so that the light penetrates very deeply. The limit of transparency is almost always over 14 meters in depth. The water of the lake is greenish in color at the shore, and becomes bluer, even ultramarine, toward the center.

Lake Prespa is not as transparent as Lake Ohrid, and its transparency, along with the color, changes from one spot to another. A white shelf or table can be seen at a depth of 2.6 meters 200 meters offshore, and in the center of the lake, up to a depth of 7.2 meters.

Lake Doiran has an area of 42.7 square kilometers (27.1 square kilometers belong to Yugoslavia). It is 10 meters deep and its surface is 148 meters above sea level. It is fed by several streams, which are dry in summer, and by wells at the bottom of the lake. The morning temperature of the lake surface in August is 25-26.6 degrees centigrade, between 15.2 and 15.5 degrees in the first half of October and increases by 1600 hours to 17.2 degrees. The temperature decreases toward the bottom, faster in summer (in August 3.6 degrees at a depth of 6 meters) than in autumn (in October 1.1 degrees). A temperature jump with a difference of 2.5 degrees centigrade in a layer between 2 and 4 meters deep was found in August, but it is not constant. It disappeared at the end of August and reappeared several days later. The water is yellow to dark green in color. It is not very clear because of suspended clay particles. Therefore, the transparency of this lake is not so good as that of Lake Prespa. A white table can be seen in August at a depth of 0.6 meter and in October at a depth of about 3.6 meters.

Lake Scutari is of different origin. At its location a depression was primarily formed which was changed by karst erosion and cirque formations into a large karst field. When the western part of the Balkan Peninsula lowered in a later period, this field became inundated by sea water; therefore, it is a crypto-depression -- a field which is constantly under water. The bottom of Lake Scutari inclines toward the northwest; it is 6-7 meters in depth, and along the northwest shore there are nine "eyes," underwater cirques, 8-44 meters in depth. Lake Scutari is the largest lake of the Balkan Peninsula, with an area of 369.7 square kilometers, 221.7 square kilometers belonging to Yugoslavia. The lake's level is subject to substantial changes, since its depth increases 2.6 meters (in some years, up to 3.6 meters) during the period from the end of summer up to the beginning of winter. This is caused by dry summers and heavy, late autumn rains. Very often the surrounding plains are flooded over an area of 530 kilometers. The water of this lake is fresh, although it contains more chlorides than the water of other lakes in Yugoslavia. In June, the temperature of the lake water sharply decreases from the surface toward the bottom, from 22.0 degrees centigrade at the surface to 10.7 degrees at a depth of 25 meters.

The layer of the temperature-jump phenomenon lies between 3 and 15 meters below the surface. In some spots it is so sharply pronounced that the temperature decreases 2.2 degrees centigrade for each meter of depth. This is caused by the influence of the cold spring water from the sides and bottoms of the "eyes."

The beds of some other karst lakes also are crypto-depressions since their bottom is below the sea level because of reasons mentioned above. As a rule, the formation of these beds is caused by several factors. Thus the bed of Lake Vranka, with an area of 30.2 square kilometers, was formed by anticlinal movements, and has on its shores and bottom several whirlpools called "virovi." The bed of Lake Prokljan, with an area of 11.1 square kilometers, was formed in a depressed valley around the mouth of the Krka, downstream from Skradin. The Karinsko More, with an area of 5.5 square kilometers, and the Novigradsko More, with an area of 28.5 square kilometers, are of the same type, both being near the mouth of the Zrmanja River. Their beds are in synclinal depressions. These seas are connected by the Ribnica Straits, and the Novigradsko is connected with the Adriatic through the Maslenica Straits. The surface water of Prokljan is salty; the salt content is 11.3 per mill, but it increases to 25.4 per mill at a depth of only 4 meters. The Novigradsko More has a salt content of 14-15 per mill at the mouth of the Zrmanja, while it is higher than 30 per mill in other parts.

The water is salty also in some other crypto-depressions such as Njivica on Krk, Muravnjak on Dugi Otok, Blato and Mljet, etc.

The karst-type lake is developed in limestone areas with typical karst formations. They differ as to origin. They are found especially in the typical karst area between the Ljubljanica and Bojana rivers. The smallest of them were formed in sinkholes. Such, for instance, are Lake Ponikva on Krk Island; Lake Savino (about 1,000 meters) in Prokletije, south of Gusinje; Lake Zagubica in eastern Serbia, from which the Mlava River originates; and others.

Of fluvial and karst origin are the lakes in such places where the normal river bed was closed by a transversal wall. Such are lakes Gornji and Donji in the Pliva River valley above Jajce, and the Plitvice lakes in the Korana river valley. These lakes are part of a string of 18 small lakes between 504 and 635 meters above sea level, and occupying an area of 2 square kilometers. The largest are Lake Kozjak (0.76 square kilometer) and Lake Proscan (0.66 square kilometer). All lakes are formed as terraces, one below the other, and connected by swift waterfalls. Some of these lakes are very deep, 24-50 meters, clear and quite transparent, and blue or greenish in color. Lake Svica near Otocac (0.65 square kilometer) is of similar origin. It is in the valley of the Svica River and its bed represents a valley closed by travertine.

A large number of karst fields and valleys become seasonal lakes during the period of heavy rains and snow thaws because the abysses are not able to carry away the total influx of water. The duration of flood depends upon the length of the rainy period and upon the capacity of abysses. All such lakes receive their water through temporary creeks and streams or through underground rivers and wells on their bottoms. The typical representative of this group of lakes is the above-mentioned Lake Svica. There are three groups of abysses in its bed, /each/ with an opening of 26 square meters. They carry away the water from the lake and the bed is mostly dry during summer. When the Svica River is at a high water level, the lake reaches a depth of 27 meters, at times a depth of 35 meters.

Lake Cerknica in Slovenia is a member of this group. It exists for about 10 months out of every year, from autumn to the end of July, during which period it covers about 38 square kilometers of the Cerknica valley. In summer, a salty lake remains with an area of only 0.6 square kilometer in the southwest portion

of the valley, the so-called Zodnji Kraj area. The Glamocko Polje, Dabarsko Polje, and Fatnicko Polje are flooded for 6 to 7 months. Three quarters of the Mostarsko Blato (about 25 square kilometers) are flooded from December to April because the period of heavy rains extends here from October to April. Some parts are covered with water 6 meters deep. Some smaller parts are covered with water, even late in summer, and that is why that area is called "blato" (mud). These fields are flooded for such a long time because their bottoms are as low as the river channels that constantly carry water, and the abysses are much to small to be able to carry away the entire influx of water. The Kupresko Polje, Duvanjsko Polje, and Gatacko Polje drain much faster. The Duvanjsko Polje is flooded for only about 10 days. The Livanjsko Polje is now, after reclamation, flooded for a shorter period, 2-3 months. Formerly the flood lasted three times longer.

There are many small river lakes along all larger rivers in the Pannonian basin. Their beds are isolated meanders, parts of the former river bed, and therefore they are called dead or old waters. All these lakes are a type of fresh-water swamp. Some of them are quite large. Most of them constantly contain water which is renewed during floods. In such stationary swamps, the water becomes salty when it is not renewed. The section of western Backa between Telecka and the northern frontier has very many such alkaline swamps. A special industrial activity, the production of potash, formerly developed around them. The best known sulfuric alkaline-muriatic lakes are Lake Palic at Subotica, with an area of 4.2 square kilometers, and in the Lake Rusanda Banat (near Melenci), a muddy lake with alkaline-muriatic water, with an area of about 1.5 square kilometers.

Most numerous but also smallest are the lakes on high mountains, 1,120 to 2,470 meters above sea level, especially from Durmitor to Treskavica, on Triglav, Prokletije, and Sar Planina. Their beds were formed by ice erosion. Some of them, Skrcka lakes on Durmitor and most of the lakes on Sar Planina and Bjelasica, have beds dug into cirques. In some other cases, Lake Sisko on Bjelasica and Lake Pesica on Treskavica, the beds are also in cirques but covered with moraine walls, or the beds are in depressions between moraines, such as lakes Poscen and Riblje on Durmitor. The third group of lakes contain deposits of moraine material, such as Lake Platno on Treskavica and Lake Biograd on Bjelasica, or contain moraine deposits along the slopes on their periphery, such as Lake Borac on Prenj, Lake Zmijinje on Durmitor, and lakes Belo and Crno on Sar Planina.

Lake Plav at the northern slope of Prokletije (area about 5 square kilometers, depth 9.5 meters, 901 meters above sea level) contains a number of moraine walls from Plav to Novsic village. Its bed was formed by ice erosion in strong rock and represents the lowest part of the frontier ice basin. Of the same origin are the beds of the romantic Lake Bohinj with an area of 3.15 square kilometers, and of Lake Bled, with an area of 1.4 square kilometers, southeast of Triglav. Their valleys are surrounded by a limestone partition. Both lakes are up to 45 meters deep.

All mountain lakes are clear and greenish or blue in color. Some of them are very cold. The temperature of Lake Platno is 8 degrees centigrade in summer. Some of the small lakes are surrounded by swamp grass. Closer to the mountains they are surrounded by fiber grasses, as in the instances of lakes Riblje and Poscen.

The water level in all larger lakes fluctuates during the year. These variations are less pronounced in lakes without outlets or with but a few small tributaries than in lakes with large tributaries. This can be seen by comparing lakes Bled and Bohinj. Both are in the same climatic area and the range of annual precipitation is about the same over the drainage areas of both lakes (about 8 per cent of the annual precipitation; see Figure 2 below), but the former does not have any tributaries or outlets and the latter has the Savica tributary and the Sava Bohinjka stream. The drainage area of Lake Bohinj also receives more precipitation (about 279 centimeters annually) than the drainage area of Lake Bled (on the average, 171 centimeters of precipitation). Therefore the fluctuations of the water level of Lake Bohinj are wider than those of Lake Bled (Figure 2).

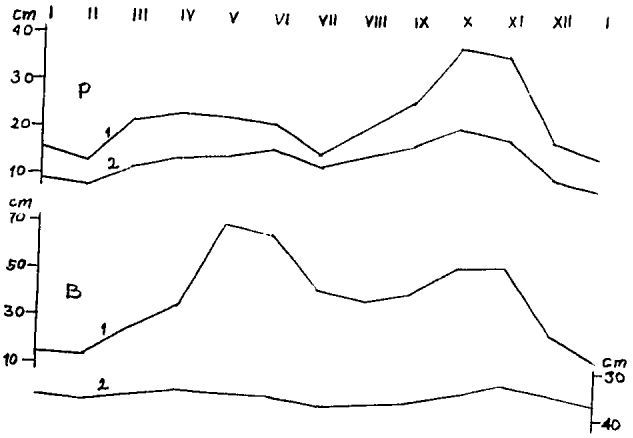


Figure 2. Annual Range of Precipitation (P) in the Drainage Areas of Lake Bohinj (1) and Lake Bled (2) and the Water Level (B) of Both Lakes From 1923 to 1940.

The same kind of differences are found between lakes Scutari and Ohrid. The former has several larger tributaries, such as the Crmnica, Crnojevica Rijeka, Moraca, and the Proni Sat, and its outlet is the Bojana River. Lake Ohrid does not have any significant tributary, but the Crni Drim carries its water off. The orographic factor is even more important here. The drainage area of Lake Scutari includes valleys and high mountains from Prokletije over Bjelasica, Lola, Lisac, and Lovcen to Rumija, with an average annual precipitation of 200 centimeters.

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Lake Ohrid has a very limited drainage area, receiving annual precipitation at 86 centimeters. The Moraca, the largest tributary of Lake Scutari, is at especially high stage late in autumn and in spring, but much lower in summer. Therefore Lake Scutari shows sharp periodic fluctuations of the water level of 206 centimeters. Fluctuations of the water level in Lake Ohrid are seven times less -- 30 centimeters on the average (Figure 3).

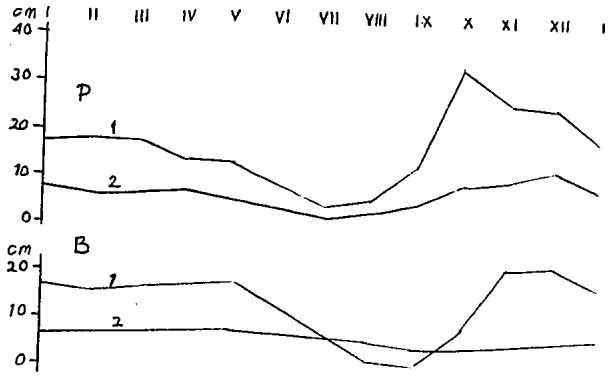


Figure 3. Annual Precipitation Range (P) in the Drainage Area of Lake Scutari (1) and Lake Ohrid (2), and the Water Level (B) of Both Lakes from 1923 to 1940.

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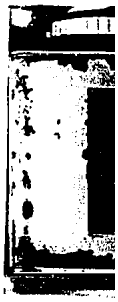

## RIVERS

Yugoslavia's rivers flow in various directions according to their geographic location and orographic configuration. The rivers flowing eastward empty into the Black Sea, southward, into the Aegean Sea, and southwestward, into the Adriatic Sea. The watershed between these three drainage areas consists of mostly mountain ranges, partly highlands, and only locally plains. The hydrographic knot of these drainage areas is far in the south of the country on Drmanska Glava (1,364 meters), which is on top of Crnoljeva Mountain. The existence of the Pannonian Sea in young Tertiary caused the watershed between the Black and Aegean Sea to shift far toward the south, and the watershed between the Black and Adriatic Sea disproportionately more toward the western frontier of the country. All mountain systems were formed in that period. Therefore, 70 percent of our entire country is within the drainage area of the Black Sea.

There are differences between the rivers of the mentioned drainage areas with regard to the annual water level range, the fluctuations in water level, and the size of tributaries. All this is connected with the precipitation in each of the drainage areas.

All rivers of the Black Sea drainage area flowing through Yugoslavia have a regular gradient; it gradually decreases from the source toward the mouth. The rivers in mountain areas very often flow through rocks and their gradient is in steps. It is sharper in the upper reaches through rocks, and lower when the rivers become wider in plains. Such rivers are the Una, Bosna, and Drina with the tributaries Lim and Djehotina, Juzna Morava, and Ibar. The Bosna's tributaries, the Usora and Krivaja, have almost a regular gradient, as do the Ibar's tributaries, the Sitnica and the Raska. The former group of rivers, flowing through plains, has a lower gradient than the second one. The average gradient of the Sava from the source to the mouth is 0.81 per mill, the Sitnica, 0.76 per mill, and the Kupa, 1.04 per mill. The Vrbas flows mostly through mountains and has an average gradient of 4.3 per mill and the Ibar, 3.74 per mill. Some mountain rivers have even higher gradients: the Ibar's tributary, the Studenica, 14.9 per mill; the Drava's tributary, the Dravinja, 16.4 per mill; the Toplica's tributary, the Bresnicka, 24.7 per mill; and the Rasina's tributary, the Grasevacka, 30.9 per mill.

Yugoslavia's largest rivers are within the Black Sea drainage area: the Danube, Drava, Tisa, Sava, and Morava. Only the Sava and the Morava, with their tributaries, are entirely (from the source to the mouth) within Yugoslavia. The Danube and its tributaries mutually influence each other as to the water level. Upstream from the mouth of its large tributaries, the Danube imposes its water level to their lower reaches. Downstream from the mouths of its large tributaries, the tributaries influence the water level of the Danube. This mutual influence can be observed by the average monthly water levels.

The Danube has the characteristic of an Alpine river up to Novi Sad. There is not much water in its drainage area during the cold months from October to February, and there is very much water there from April to June. High water levels are caused partly by heavy rains in early summer. The Danube's character changes somewhat downstream under the influence of the Tisa, Sava, and the Morava. High water prevails from March to June, since snow in the mountains begins to melt even earlier. Low water obtains earlier in autumn (from August to October) because there is not much rain, and in January because of large quantities of snow. The differences in the annual water-level periods exist east and west of approximately 20 degrees east longitude.

The Drava and Sava, with their tributaries, have two typical high water levels (the first in spring and the second late in autumn) and two low water levels.



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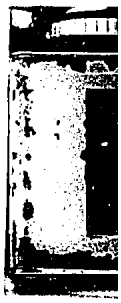

Winter and summer minimum water levels are about equal in all mountain rivers in the northwest (for instance the Savinja), while the summer minimum is more typical in other Sava tributaries (for instance, the Una and Drina). Rivers east of 20 degrees longitude are typified by a single annual water-level period, high water in spring and low water late in summer.

The rivers within the Aegean Sea drainage area have about the same water-level periods as the rivers in the eastern part of the Danube drainage area. The highest water level is in April or May and the lowest in August or September. Examples of this are the Vardar, Pcinja, and the Crna Reka. All valleys in this drainage area show tectonic influences. At present, the Vardar valley consists of several valleys depressed along the dividing line and separated by rocks. Therefore, the Vardar's gradient is irregular: it increases through rocky territory, although it decreases over the whole distance from its source to its mouth.

The rivers of the Aegean Sea drainage area show wide variations in the amount of water they carry. For instance, 565 cubic meters of water per second flow in the Vardar River at high water level, and at the lowest water level, 31.2 cubic meters per second, that is, 18 times less. Many smaller rivers dry up in summer because of drought and leave dry, sandy beds, as with the Bregalnica's tributary, the Kriva Lakavica, and most of the Pcinja's tributaries.

The rivers of the Adriatic drainage area have a different aspect. This is the area with most rain late in autumn, and there is another additional maximum in one of the spring months, while the summer remains dry -- increasingly so southward. Large rivers in this area are fed by melted snow from medium and high mountains. Therefore, they have two equally high water levels, the first one in March or April and the second in November or December. However, the low water late in summer is more typical than that in winter. Characteristic examples for water-level movements are the Krka, Neretva, and the Moraca. The annual amount of water carried by rivers of the Adriatic drainage area is quite large because of the high amount of precipitation throughout the year.

The gradient of rivers in the Adriatic drainage area is very irregular. None of the normal rivers in this area has an equalized gradient. The rivers penetrate with difficulty through steep, often narrow and deep, canyons, forming currents and high waterfalls. When the rivers widen in valleys or fields, the gradient decreases so much that it appears on a graph as abrupt steps. Most irregular is the gradient of the Cetina, since it increases from the sources toward the mouth because of high waterfalls in the lower reaches upstream from the town of Zadvarje. Generally speaking, all large rivers have a substantial gradient: the Krka, 4.4 per mill; the Cetina and Neretva, 4.7 per mill; the Zrmanja, 5.0 per mill; and the Moraca, 19.7 per mill.

The volume of water carried by Yugoslav rivers varies widely. The volume of flow of the Danube at Vienna is 61.15 cubic kilometers annually. After having received the water from several larger tributaries downstream, and after having entered Yugoslavia at Bezdan, the flow of the Danube increases to 70.64 cubic kilometers. Still farther downstream, after having been joined by its large tributaries, the Drava, Tisa, and the Sava, the volume of the Danube increases at Pancevo to 169.66 cubic kilometers and at Orsava to 175.34 cubic kilometers. This increase is to be attributed to the Morava, Mlava, Karas, Nera, the Pek, and other small tributaries in the Djerdap region. It should be pointed out that the Neretva has a large annual flow of 8.83 cubic kilometers, while the Vardar carries only 5.90 cubic kilometers of water to the Aegean Sea annually, although its drainage area is three and a half times larger than that of the Neretva. This reflects the disproportionate amounts of rain in these drainage areas.

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In addition to normal rivers, which have normal valleys and flow on the surface from the source to the mouth, there is another group: underground rivers, which prevail in the limestone areas. Leaving their source, they flow for a short distance on the surface of the earth and then suddenly disappear, dropping into abysses. The valleys of the underground rivers are as irregular as their flow. Some valleys have very steep sides right at the river source, which is under steep walls, such as the Ljubljanica, Rijeka Dubrovacka, and the Mlava. Some valleys are closed at the abyss, that is, their walls meet at the abyss, so they are called blind valleys. Such is the valley of Brestovica on the Kucaj or of Jaruga in Stajnicko Polje below Mala Kapela.

The distance these underground rivers flow on the surface rivers is mostly very short; however, the underground channels continue for a longer distance. The longest underground rivers are: the Trebisnica between Bilec-Trebinje-Zavala (93.8 kilometers), the Lika at Gospic and Perusic (78.1 kilometers), and the Mreznica in the area between Ogulin and Karlovac (62.6 kilometers). It has been established that some of these rivers go underground several times and reappear on the surface a number of times but under different names. Some of these are the right tributaries of the Ljubljanica (the underground riverr Trbuhovica, Loski Obrh, Strzek. and Rak) and the left tributaries of the Ljubljanica (the underground river Pivka and its tributary the Panoscica). Each of them disappears underground each time on a lower level as it approaches the Ljubljanica, and each one flows under the ground for a certain distance. The Pivka and Rak originate in Planina Polje from a larger number of wells, which form the underground river Unec. After flowing underground, the river appears at Vrhnika as the source of the Ljubljanica.

The Trebisnjica is an opposite instance. This river, after having entered the abysses, flows in underground channels partly toward the Neretva into Dersansko and Svitavsko Blato, and the larger part flows toward the Dubrovacka River and toward Bistrine in Stonski Bay. The sources of these rivers are sometimes very strong. The Mlava, for instance, originates in Zagubicko Vrelo and there powers a water mill with six wheels. The Trebisnjica carries a substantially large volume of water, although it is fed mostly by wells. It carries about 145 cubic meters of water per second in April, but only 13 cubic meters per second at the end of June.

It is characteristic that some karst rivers carry water constantly, as the Rakitnica in Dolenjsko and the Gracanica in the southwest end of Gatacko Polje, while the others seasonally dry up. An excellent example of this type is the Recica in Glamocko Polje, which is without water during the three hottest and driest months, from July to September, and carries high water during the very rainy month of November. Important also is the fact that nearly contiguous reaches of surface rivers will have dry beds for different lengths of time. The reason for this is that the abysses are of various sizes, and they cannot take the same quantity of water off within the same length of time; also, one section of the bed might have more abysses than another nearby section, which will take off larger quantities of surface water. The Recina's bed is also not dry the same length of time every year.

It seems that the water level of the underground rivers is higher closer to the abysses, as was established in the case of the Trebisnjica. The reason for this lies in the high gradient and in the fact that the abyss cannot take off the water as fast as it flows into the abyss.

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